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Red-Cockaded Woodpecker Colony Status and Trends on the Angelina, Davy Crockett and Sabine National Forests

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SUMMARY

The status of red-cockaded woodpecker *(Picoides borealis)* colonies was determined for the Sabine and Davy Crockett National Forests in 1987 and annually on the Angelina National Forest from 1983 through 1988. National forest records were used to estimate woodpecker population trends on the Sabine and Davy Crockett National Forests. Populations were declining severely on all three national forests Dawn and dusk roost checks indicated that about one-fourth of all active colonies contained only a single red-cockaded woodpecker. Habitat measurements and statistical analyses indicated that the presence of hardwood midstory foliage in colony areas and colony isolation were the main reasons for the decline. Habitat fragmentation appeared to have a negative affect on woodpecker group size. An aggressive hardwood midstory removal program and frequent prescribed burns in colony areas are recommended. Also recommended are the use of the irregular shelter-wood cutting method within a 1,200-m (0.75-mi) radius of active colonies rather than clearcutting and no regeneration cutting within a 400-m (0.25-mi) radius of active colonies until populations exceed 50 active colonies.

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INTRODUCTION

Red-cockaded woodpeckers *(Picoides borealis)* evolved in the fire climax, open-pine forests of the Southeastern United States. Red-cockadeds do not tolerate the presence of hardwood trees well, particularly in the immediate vicinity of the group of pines that form the woodpecker colony (Conner and O'Halloran 1987). They excavate roost and nest cavities in the pines comprising the colony. In the past, fire prevented the extensive growth of hardwoods in the colony areas and foraging habitat of the red-cockaded woodpecker. The present practice of exclusion and reduction of fire appears to be a major contributing factor to the decline and endangered status of this woodpecker (Jackson and others 1986).

Unlike typical woodpeckers whose social unit consists of a male and female, the red-cockaded's social unit is a group that consists of the breeding male and female and one to several offspring (usually males) from previous broods (U.S. Fish and Wildlife Service 1985). These additional group members, often called helpers, help feed the young of the breeding pair of woodpeckers. A woodpecker group (a clan) defends a relatively large territory and has a home range that can vary from less than 50 ha (125 acres) to over 400 ha (1,000 acres>, depending on habitat quality. This "cooperative breeding system" is also seen in other bird species. Such a breeding system may be an adaptation to resource limitation where it is unlikely that dispersal will lead to successful independent reproduction (Stacey and Ligon 1987). A low supply of suitable cavity trees may have been the resource limitation affecting the evolution of the red-cockaded woodpecker's breeding system.

A red-cockaded woodpecker clan may use from 1 to 30 living pines as cavity trees (U.S. Fish and Wildlife Service 1985). Their roost and nest cavities in pines are usually clustered relatively close together. The aggregation of cavity trees used by a clan and the 61-m (200-ft) buffer zone around the cavity trees is called a colony area. Red-cockaded woodpeckers peck small holes, called resin wells, around the entrance to their cavities, and as a result pine resin flows down the bole of the cavity trees. This behavior benefits the woodpecker because the sticky resin serves as a barrier against their major predator, the rat snake *(Elaphe obsoleta)* (Jackson 1974). As cavity trees age, the surface of the tree bole around the cavity entrance becomes devoid of cambial and phloem tissues as a result of continual pecking by woodpeckers at resin wells. This relatively circular area around the cavity entrance is called the plate.

In order to properly manage red-cockaded woodpeckers it is important to have a knowledge of red-cockaded woodpecker population levels and trends. The red-cockaded woodpecker has been legally defined as an endangered species since the early 1970's. Major population declines in the past resulted from extensive timber harvesting throughout the South and the loss of old growth pines that serve as cavity trees (U.S. Fish and Wildlife Service 1985). Accurate data on population size and current trends are necessary for early identification of population changes and to provide input for management decisions. If population declines are detected, concurrent habitat data are needed to evaluate possible causes of population changes. Red-cockaded woodpecker colonies (aggregations of cavity trees) and habitats on the Angelina, Davy Crockett, and Sabine National Forests in eastern Texas were visited and evaluated to determine current status and estimate short-term population trends. National forest data for the Davy Crockett and Sabine National Forests were also used.

STUDY AREAS

The Angelina, Davy Crockett, and Sabine National Forests are three of four national forests located in eastern Texas. Of the 62,423 ha (154,185 acres) of

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federally owned forested lands on the Angelina National Forest (ANF), approximately 49 percent is to the northeast and 51 percent is to the southwest of Sam Rayburn Reservoir. Red-cockaded woodpeckers on the northeastern portion of the ANF are found in stands composed mainly of loblolly *(Pinus taeda)* and shortleaf *(P. echinata)* pines. Woodpecker colonies on the southwestern portion of this National Forest are found primarily in longleaf *(P. palustris)* pine forests, which comprise 15 percent (9,653 ha [23,843 acres]) of the total ANF. Considerable hardwood midstory is present within woodpecker colony areas, particularly on the north end of the ANF. Active colonies northeast of the reservoir are 34 km (21 mi) or more from active colonies southwest of the reservoir. This distance and the Sam Rayburn Reservoir may serve as barriers to extensive genetic mixing of red-cockaded woodpecker populations as the reservoir varies between 3.8 and 6.4 km (2.4 and 4.0 mi) wide where it divides the ANF.

The Davy Crockett National Forest (DCNF) is 65,359 ha (161,437 acres) in size and 32 km (19.9 mi) west of the ANF. The DCNF is composed primarily of loblolly and shortleaf pines but has considerable hardwood vegetation mixed in with the pine. The two ranger districts, Neches and Trinity, are 31,040 ha (76,669 acres) and 34,319 ha (84,768 acres) in size, respectively. Less than 1 percent (169 ha [417 acres]) of the forest on the DCNF is primarily longleaf pine.

The Sabine National Forest (SNF) is 63,923 ha (157,890 acres) in size and 15 km (9.3 mi) east of the ANF. The SNF is also composed primarily of loblolly and shortleaf pines with considerable hardwood vegetation mixed in with these pines. The two ranger districts, Tenaha and Yellowpine, are 30,042 and 33,881 ha (74,204 and 83,686 acres) in size, respectively. About 5 percent (2,902 ha 17,168 acres]) of the SNF is composed of longleaf pine forest, most of which is on the southern extreme of the Yellowpine Ranger District.

Most red-cockaded woodpecker colonies on the ANF, DCNF, and SNF are associated with two types of soils. Colonies on the southern portions of the ANF and SNF are typically located on deep loamy sands (Tehran and Letney soil types) containing materials of volcanic origin (Neitsch 1982). These soils contain very little organic material, and as a result have a low water holding capacity. High soil temperatures on hot summer days can negatively affect hardwood vegetation, which helps preserve the open parklike conditions of the longleaf pine forest on these sites.

Red-cockaded woodpecker colonies on the northern portion of the ANF and SNF and most of the DCNF are typically located on shrink-swell clays of the Woodtel and LaCerda soil types (Fuchs 1980). As the moisture content of these clays changes, the clays expand and contract, often stripping root hairs from the roots of trees growing on these sites. Basic salts are also found in these soils, which further aggravate the plant-moisture relationship. Thus, soils where most active red-cockaded woodpecker colonies are located are very stressful sites to many plant species. Red-cockaded woodpeckers may have persisted on these stressful sites longer than other areas of the forest because less hardwood vegetation was present.

Historical Perspective

Fossil pollen records suggest that after the last glaciation, approximately 12,000 years B.P. (before present), the extensive pine forests of the South began to spread toward eastern Texas from Florida (Webb 1987). Pines have been widespread in eastern Texas for the past 4,000 years.

Although timber harvesting occurred in eastern Texas prior to 1880, the “bonanza era” harvesting spanned the years 1880 to 1930 (Maxwell and Baker 1983). By 1917, 1.2 million ha (3 million acres) of virgin forest remained in eastern Texas (McWilliams and Lord 1988). About 3.25 million ha (8 million acres) consisted of cut-over land of which only 21 percent had successfully regenerated into second growth stands (Foster and others 1917). The boom era of Texas lumbering ended around 1924 when timber supplies were exhausted and many large mills closed (McWilliams and Lord 1988). In 1933, 267,000 ha (660,000 acres) of cut-over lands were authorized to be purchased to establish the national forests in Texas. With the help of the Civilian Conservation Corps, the USDA Forest Service began reforesting the four newly established national forests (Maxwell and Baker 1983).

How red-cockaded woodpeckers survived the 50 years of bonanza era harvesting is unknown. The ages of many existing cavity trees used by the woodpecker today (Conner and O'Halloran 1987) indicate that not all pines were cut during the initial harvest of virgin timber. Colonies were apparently able to persist in areas where some pines were not cut. Longer timber rotation ages and conservation practices on national forest lands in Texas and throughout the South are the major reasons why red-cockaded woodpeckers are more abundant on national forest lands than private lands today.

METHODS

Locating Cavity Trees

Angelina National Forest.-Starting in the winter of 1982-83 and continuing through the 1988 breeding season, 301 red-cockaded woodpecker cavity trees on the ANF were located, tagged, painted (single aqua band 1.5 m [5 ft] up from groundline), and mapped. The location and status of many colonies on the ANF were already known from other studies, some of which had begun as early as 1978. Initially, maps showing the location of some cavity trees were provided by the Supervisor's Office, National Forests of Texas, in Lufkin, TX. Areas around known cavity trees were searched for additional cavity trees by circling around colony areas using a zig-zag path that extended out approximately 300 m (985 ft) from the colony center. Using National Forest System (NFS) continuous inventory of stand conditions (CISC) records of the ANF from 1978 through 1988, other areas of mature pine forest (more than 50 stands >50 years old, each covering an area of about 8 ha (19.7 acres) and farther than 300 m (985 ft) from known red-cockaded woodpecker colonies) were located and searched for unmapped colonies.

Davy Crockett and Sabine National Forests.— Maps showing the location of known cavity trees on the DCNF and SNF had also been provided by the National Forest Supervisor's Office in Lufkin, TX. From February through June we visited all known red-cockaded cavity trees on the DCNF (in 1987) and SNF (in 1987 and 1988) that had been listed in the NFS records. We tagged, painted (aqua band), and mapped all cavity trees on the SNF. Additional mature pine stands were also searched for new cavity trees and colonies in areas adjacent to existing active and inactive colonies to account for possible minor changes in colony location through time.

Determining Cavity Tree Status

Each cavity tree was visited during the months of April and May to determine its status relative to use by red-cockaded woodpeckers. Visits were carried out as follows: ANF, 1983 through 1988; DCNF, 1987; and SNF, 1987 and 1988.

Determination as to whether or not a cavity tree was active was based on whether or not there were active resin wells on the cavity tree. Cavity trees without any active resin wells were considered inactive (Jackson 1977). Resin wells were judged to be active when bark bordering the well was red, indicating recent pecking (Jackson 1978), and if clear, fresh resin was flowing from the well. Trees were examined closely from all sides to ensure that the fresh resin was not a result of early stages of cavity enlargement or foraging sites of the pileated woodpecker ***(Dryocopus pileatus),*** cerambycid beetle oviposit sites, yellow-bellied sapsucker ***(Sphyrapicus varius)*** feeding sites, or some other injury to the tree.

Determining Colony Status

To determine if a group of cavity trees in an area represented an active colony, resin well activity, juxtaposition of the trees, amount of bark scaling, and activity of adult red-cockaded woodpeckers were all taken into consideration (Jackson 1977, 1978). The presence of young in nest cavities, signs of incubation, and other activities of adults helped to determine whether or not a group of cavity trees was an active colony. Because not all clans breed each year, some colonies were judged active based solely on activity at resin wells and scaling in the colony area. Groups of cavity trees where no nesting attempt or adult woodpeckers were detected were tentatively judged to constitute an active colony if they contained one or more cavity trees with minor (one to three active wells), moderate (four to six active wells), or copious (more than six active wells) fresh resin well activity; obvious bark scaling; and were at least 400 m (0.25 mi) from an adjacent colony (the 400 m was defined by an 800-m [0.5-mi] diameter circle centered on the cluster on cavity trees). This 400-m (0.25-mi) distance is used by the Forest Service as the minimum distance for establishing recruitment stands for red-cockaded woodpeckers (USDA 1984). The distance of 400 m was initially determined by calculating the probabilities of encountering another woodpecker colony at varying distances from active colonies. The method we used to determine colony status deviates slightly from the method described by Harlow and others (1983) and was used because it provided a higher estimate of the number of active colonies.

Each colony (on all three national forests) showing any sign of activity was visited once a week (ANF, 1983 through 1988; DCNF and SNF, 1987) for the duration of the nesting season (from mid-April to the end of June) or until young were audibly present in the nest cavities. During April and May of 1987, dawn and dusk visits were made to all active colonies to determine where woodpeckers were roosting and how many were present in each clan. These checks were also used to make final determinations on colony activity status. Dawn and dusk visits to colonies on the ANF were also made in 1988 to determine clan size in each active colony.

Records of colony status in past years on the DCNF and SNF were available in selected areas from NFS colony record data. These data were compared with the data we had collected to evaluate possible population trends. The NFS data may not be precisely comparable with our 1987 data because of possible differences in methods used to evaluate cavity tree activity and differences in the experience levels of observers. This is especially true for the SNF 1978 data, which was collected at a time when the experience level of field personnel was quite limited. Trend data for the ANF (1983 through 1988) are based on our own data, which we consider to be highly accurate.

Causes for population trends were evaluated only on the ANF and DCNF because of the questionable comparability of the 1978 SNF data. We suspected that colony isolation might be contributing to the loss of active colonies. We measured this isolation factor on the ANF in 1983 and DCNF in 1981 (from data supplied by NFS) by counting the number of active colonies within a 2-km (1.25mi) radius of each active colony. Isolation values of colonies that were still active in 1987 were compared with isolation values of colonies that had become inactive by 1987.

An ocular, ordinal estimate (l-5; where 1 = grasses and forbes only, and 5 = dense hardwood foliage present with horizontal visibility <10 m [32.8 ft]) of hardwood midstory present in all colonies on the ANF was made in the spring of 1983 and on the DCNF in the spring of 1987 in order to evaluate the effects of hardwood midstory presence on red-cockaded population trends. On the DCNF midstory height was added to this ocular estimate to provide a more accurate measure of midstory condition.

We used aerial photographs taken in 1986 of the ANF and DCNF to try to measure relationships between cutting (regenerations cuts, southern pine beetle *[Dendroctonus frontalis]* control cuts on Federal and private lands, and past cutting for other nonforest land use such as pasture) and changes in colony status. Stands with shelterwood trees still present were not considered as having been cut. A circle with a radius of approximately 400 m (0.25 mi) was drawn on the aerial photographs around each colony that had been active in 1983. Representative stands of varying ages identified on the aerial photographs around red-cockaded woodpecker colonies were verified in the field. The area of each circle that had been cut during the last 20 years (approximately) was measured with a licor area meter. The percentage of area cut (≤20 years old) within 400 m (0.25 mi) of colonies might be viewed as a measure of habitat fragmentation and/or as a reduction in the amount of foraging habitat in close proximity to the colony. This fragmentation variable was used to compare colonies that remained active in 1987 with colonies that had become inactive and was also compared with the number of woodpeckers per colony on the ANF and DCNF in 1987. This procedure was repeated using an 800-m (0.5-mi) radius.

Using similar measures on both ANF and DCNF, we combined the data sets of active colonies on the ANF and DCNF ($n = 49$) and used Spearman correlations to compare the number of woodpeckers per colony in 1987 with our measures of cutting (the fragmentation variable), isolation, and hardwood midstory. Discriminant function analyses and logistic regression were used on a combined data set of habitat variables from the ANF and DCNF ($n = 88$, active versus inactive colonies) to evaluate possible causes for colony inactivation.

The national forest land area affected by our recommendations (forest area within 1,200 m 10.75 mil of all active colonies as well as inactive colonies that are within 5 km [3 mil of active colonies) was determined using maps provided by NFS and our 1988 data on colony status. Colonies were located on a map of each national forest, and circles 1,200 m (0.75 mi) in radius centered on each colony were traced on a transparent overlay. The resulting areas were cut out and their areas measured using an area meter. These areas were then compared to the total area of the national forests in Texas and the total area of timberland in eastern Texas (McWilliams and Lord 1988).

RESULTS

We examined 62 colonies on the ANF (1983 through 1988), 134 colonies on the DCNF (1987), and 62 colonies on the SNF (1987). In 1987, 35 percent of the colonies on the ANF, 20 percent on the DCNF, and 11 percent on the SNF were active (table 1, fig. 1). Repeated visits revealed that of these active colonies, 64 percent on the ANF, 33 percent on the DCNF, and 43 percent on the SNF produced young (fig. 1). Lennartz and others (1983) had estimated that 6 (± 12) active colonies were present on the ANF, 48 (± 24) on the DCNF, and 32 (± 55) on the SNF from partial samples taken from 1980 through 1982.

Our dawn and dusk visits to the 56 active colonies just before the nesting season showed that 23 percent had only a single woodpecker present, 53 percent had two birds, 22 percent had three birds, and about 2 percent had four birds (fig. 2). This represents an overall average of 2.02 red-cockaded woodpeckers per colony in the spring of 1987.

Our data from the ANF indicate that the number of active woodpecker colonies has been declining (fig. 3). There were 38 active colonies in 1983 compared to 19 active colonies in 1988. The 50-percent decline on the ANF over a 5-year period represents a lo-percent annual loss of active colonies. Typically, colony abandonment on the ANF was preceded by 1 to 3 years of only a single red-cockaded woodpecker being present at a colony.

Data from NFS records provide a limited trend analysis for the DCNF and SNF. These data indicate that at least 46 active colonies were present on the DCNF in 1983. The drop to 27 active colonies in 1987 represents an overall 41-percent decrease, or

Table 1.— *Red-cockaded woodpecker colony characteristics in 1987 on the Angelina (ANF), Davy Crockett (DCNF), and Sabine (SNF) National Forests*

Forest	Total colonies	Total active colonies	Total woodpeckers	Colonies with single woodpecker	Colonies with young in cavity	Active colonies withyoung+
	----------	----------	*Number*	----------	----------	*Percent*
ANF	62	22	47	4	14	64
DCNF	134	27	52	8	9	33
SNF	62	7	14	1	3	43
Total	258	56	113	13	26	**46***

+Colonies with young in cavity/total active colonies multiplied by 100.
*This percentage represents data for all three national forests.

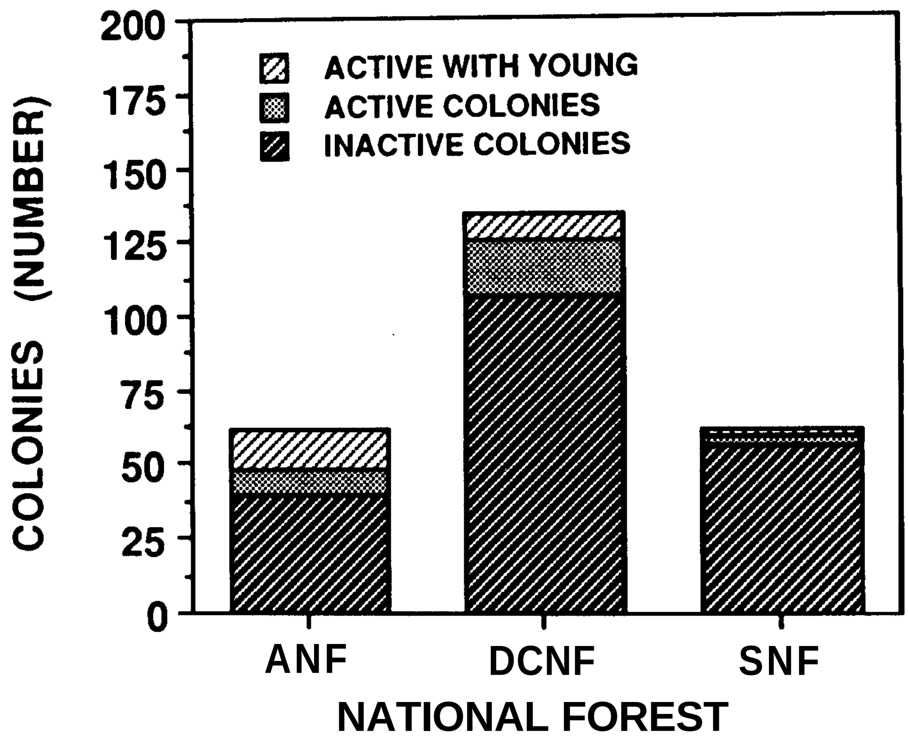

Figure 1.— *Number of inactive, active, and red-cockaded woodpecker colonies with young on the Angelina (ANF), Davy Crockett (DCNF), and Sabine (SNF) National Forests in 1987.*

an average annual loss of 10.3 percent. Perhaps a more accurate view of the population trend on the DCNF can be seen from a subset of data for the Neches Ranger District. Of 46 colonies that were active in 1981, 42 were active in 1983 (NFS records), but only 20 of these colonies remained active in 1987 (fig. 4). This indicates a 57-percent decrease over a 6-year time span, or a 9.4-percent average annual estimated rate of decline.

In 1988 the NFS informed us of five additional active colonies on the SNF (Tenaha Ranger District) that we had been unaware of while conducting the 1987 survey of this area. The appearance of the cavity trees within these five colonies (plate size around entrance, number of old inactive trees) indicated that these active colonies had been in existence for many years. Based on this new information, an adjusted estimate (assuming all five colonies were active in 1987) for the SNF for 1987 would be 13 active colonies.

An estimated minimum of 30 active colonies (25 estimated from NFS records plus the 5 additional

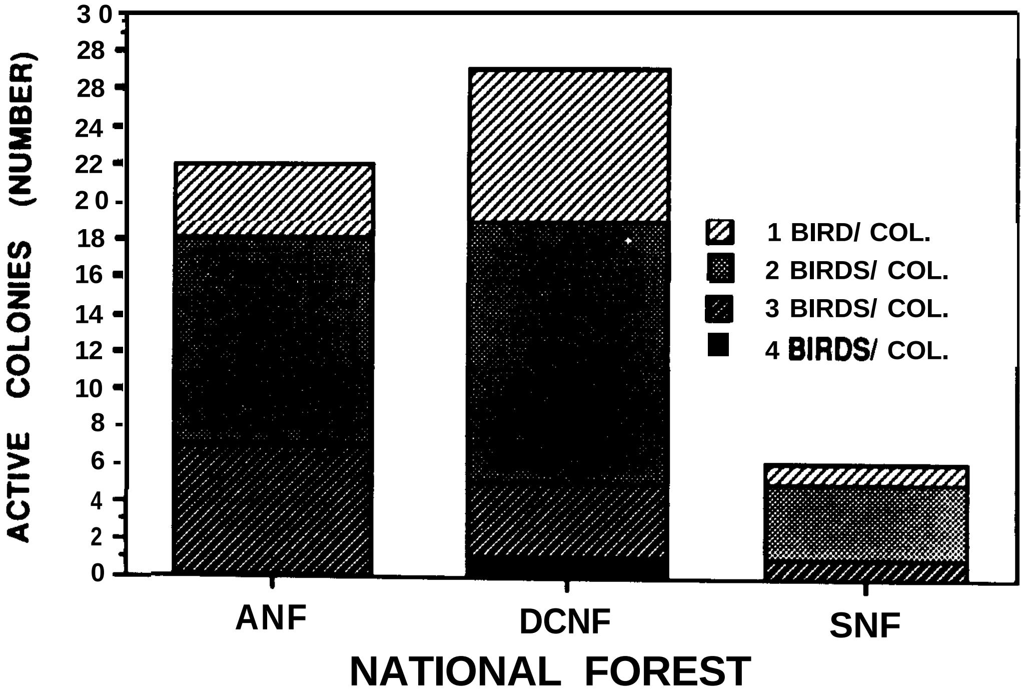

Figure *Z.-Number of red-cockaded woodpeckers per colony on the Angelina (ANF), Davy Crockett (DCNF), and Sabine (SNF) National Forests in 1987.*

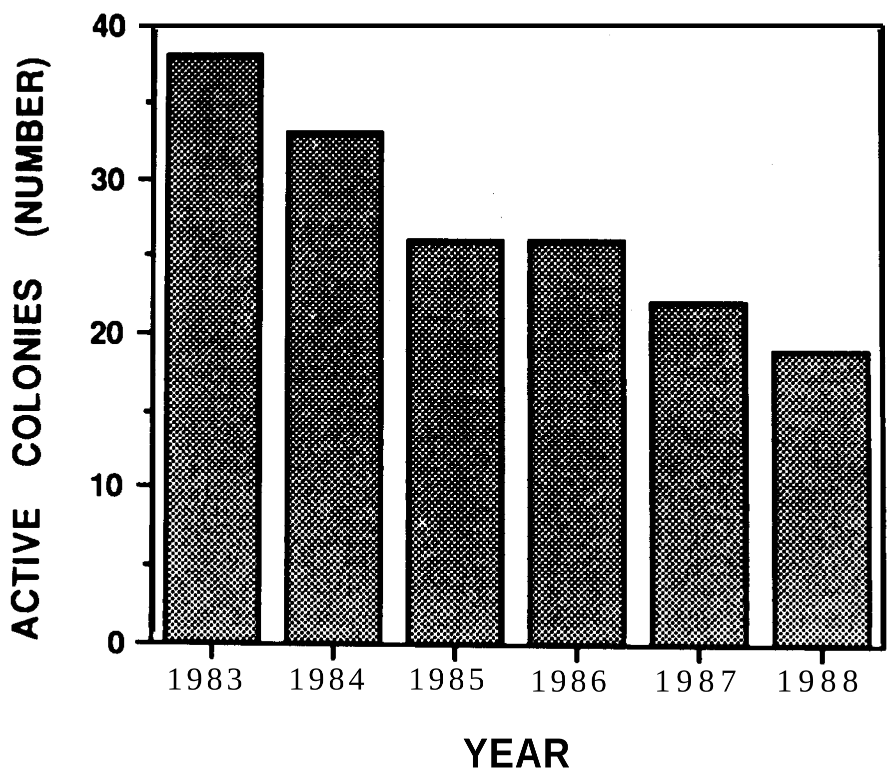

Figure 3.— *Population trend (number of active colonies) for red-cockaded woodpeckers on the Angelina National Forest in eastern Texas (1983–1988).*

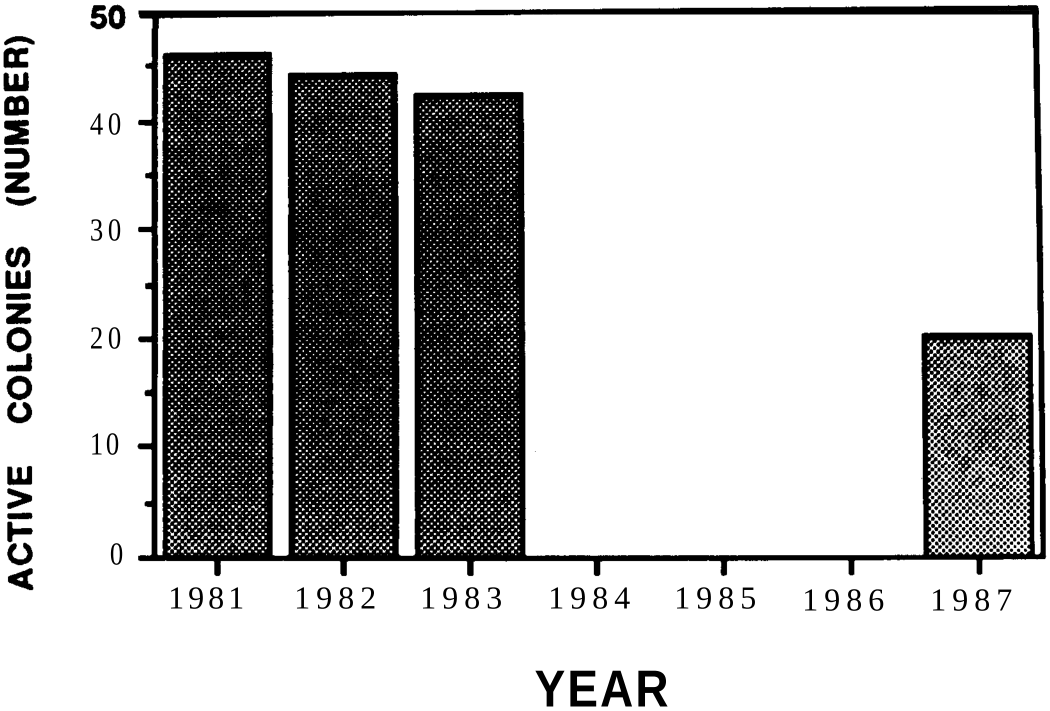

Figure *4.-Number of red-cockaded woodpecker colonies on the Neches Ranger District of the Davy Crockett National Forest in 1981, 1982, 1983, and 1987 (No data were available for 1984–86).*

colonies reported in 1988) may have been present on the SNF in 1978. Our adjusted 1987 colony estimate of 13 suggests a 57-percent decrease over a 9-year time span. This indicates a 6.3-percent average annual decline on the SNF. Our 1988 survey indicated that only 11 colonies were active prior to the breeding season. This indicates a 15.4-percent decline between 1987 and 1988. Field visits suggested that 4 (36 percent) of the 11 active colonies on the SNF in 1988 consisted of only a single red-cockaded woodpecker.

Our data analyses suggest that a primary reason for the decline is hardwood midstory encroachment in colony areas resulting from a lack of frequent prescribed fire. Many colonies had not had a prescribed fire for 5 to 10 years. On the ANF, there has been a significantly greater abundance of hardwood midstory (using the ordinal estimate) in colonies that have become inactive since 1983 than in colonies that were still active in 1987 (Mann-Whitney U = 63.5, P ~0.0005, n = 38, table 2). A similar relationship was detected on the DCNF between 1981 and 1987 (Mann-Whitney U = 201.5, P <0.03, n = 50).

We did not detect a statistically significant relationship between the combination of clearcutting and cutting to control southern pine beetles, and red-cockaded woodpecker colony inactivation on the ANF (n = 38) and DCNF (n = 50) (table 2). Univariate statistical tests (t-test) failed to detect any significant differences (P = 0.05) between colonies that remained active and colonies that went inactive on either the ANF or DCNF for the amount of cutting (total tree removal) done within 400 m (0.25 mi) of woodpecker colonies (ANF: t = 0.42, P = 0.67; DCNF: t = 0.10, P = 0.92) or the distance from a woodpecker colony to the closest clearcut (ANF: t = 0.72, P = 0.48; DCNF: t = 0.91, P = 0.37). There were insufficient data to make such tests and comparisons on the SNF.

We also failed to detect significant differences between active and inactive colonies for the measure of isolation used (table 2). Our isolation measure using the number of active colonies within 2 km (1.24 mi) of each active colony on the ANF came the closest to being significant (t = 1.31, P = 0.19, n = 38).

It is possible that high pine basal area in colony areas (aggregation of cavity trees and colony buffer zone) also contributed to the decline. Table 3 summarizes the measurements made at each colony location on the ANF in 1983 and the DCNF and SNF in 1987. Although basal area measurements at each cavity tree indicate that pine basal area in the immediate vicinity of cavity trees is appropriate (table 3), our field observations on all three national forests indicate that basal area rises rapidly about 20 m (65.6 ft) away from each cavity tree, suggesting that thinning is needed in the remainder of the colony areas.

The high significance of hardwood midstory effects on the number of active colonies on the ANF

Table 2.— *Habitat characteristics of red-cockaded woodpecker colonies that either became inactive prior to or remained active in 1987 on the Angelina (n =38) and Davy Crockett (n = 50) National Forests+*

Variable	Angelina		Davy Crockett	
	Active colonies	Colonies that became inactive	Active colonies	Colonies that became inactive
	Mean ± *SD*			
Hardwood midstory (ordinal no.)	2.1 ± 1.1	3.6 ± 1.1**	6.3 ± 2.9	7.6 ± 1.8 *
Isolation in 1988 (no. of active colonies within 2 km [1.24 mi])	3.2 ± 2.0	2.5 ± 1.6	1.7 ± 1.1	1.8 ± 1.5
Cutting in 1986 (percent within a 400 m LO.25mi] radius of colony)	14.6 ± 18.1	12.0 ± 20.4	29.4 ± 19.8	29.8 ± 19.3
Distance to closest cut in 1986 (cm on map)	0.5 ± 0.6	0.7 ± 0.7	0.1 ± 0.2	0.1 ± 0.1

+See methods section in text for a more detailed description of the variables. The Mann-Whitney U-test was used to examine differences between active and inactive colonies.
*$P < 0.05$
**$P < 0.001$

Table 3.— *Habitat variables measured at red-cockaded woodpecker cavity trees on the Angelina in 1983, Davy Crockett, and Sabine National Forests in 1987+*

	National Forest		
	Angelina	Davy Crockett	Sabine
	Mean ± *SD**		
Cavity tree age *(yr)*	114.5 ± 36.3	101.7 ± 15.4	104.2 ± 22.3
Cavity tree height (m)	25.4 ± 3.8	28.1 ± 4.3	25.1 ± 4.5
(ft)	83.3	92.2	82.4
Cavity tree d.b.h. *(cm)*	49.0 ± 8.0	50.9 ± 8.3	49.6 ± 7.1
(in)	19.3	20.0	19.5
Pine basal area (m^2/ha)	14.0 ± 5.5	10.4 ± 3.4	10.5 ± 4.5
(ft^2/acre)	61.6	45.7	46.2
Hardwood basal area (m^2 / ha)	0.8 ± 1.3	0.9 ± 1.1	0.7 ± 1.1
(ft^2 lucre)	3.5	4.0	3.1
Midstory height (m)	3.7 ± 2.3	4.1 ± 2.1	3.7 ± 2.2
(ft)	12.1	13.5	12.1

+n = 212 for Angelina, n = 351 for Davy Crockett, and n = 93 for Sabine National Forests.
*English measurements are for the mean, without standard deviation.

suggested that the effect of hardwood midstory might be masking the effects of other variables. We used a two-group discriminant function analysis (DFA) to evaluate the relative contribution of each variable in explaining the woodpecker decline on a combined data set from the ANF and DCNF. Our classification groups in the DFA were colonies that remained active in 1987 contrasted with colonies that had become inactive by 1987.

Using all variables (midstory, isolation, and cutting within 400 m 10.25 mi]), the DFA successfully discriminated between the two groups (P ~0.0001, 73 percent of all cases correctly classified, n = 88). Correlations of the original variables to the canonical discriminant axis indicated that colony inactivity was significantly associated with increasing hardwood midstory ($r = 0.80$, $P < 0.001$) and colony isolation ($r = 0.33$, $P < 0.01$).

In order to exclude the influence of hardwood midstory, a second DFA was calculated with hardwood midstory eliminated from the variable list. The second DFA (n = 88) was somewhat successful in discriminating between the two groups of colonies ($P < 0.02$, 53 percent of all cases correctly classified). Correlation analysis suggested that increasing isolation of colonies (number of active colonies within 2 km [1.24 mi], $r = 0.83$, $P < 0.001$) is also a contributing factor to colony inactivity.

We attempted to calculate a third DFA (n = 88) to examine the possible contribution of just clearcutting and southern pine beetle (SPB) cutting to colony inactivity; however, no variables entered the analysis because of low F values.

Because our hardwood midstory variable is an ordinal data type, we calculated a logistic regression to cross check the DFA results. Logistic regression (n = 88) indicated a very highly significant effect of hardwood midstory presence ($\chi^2 = 25.5$, $P = 0.001$), a significant effect of isolation ($\chi^2 = 15.7$, $P = 0.03$), and a nonsignificant effect of cutting ($\chi^2 = 0.003$, $P = 0.96$) on red-cockaded woodpecker colony inactivation.

Our dawn and dusk visits to colonies in 1987 permitted us to determine how many woodpeckers were present in each clan. We looked for relationships between the number of woodpeckers per clan in active colonies and (1) the percentage of the forest within 400 m (0.25 mi) of the colony that had been cut in the past 20 years (clearcut, cut to control SPB, or not present as foraging habitat because of some other land use); (2) the amount of hardwood midstory present, and (3) our measure of isolation. These data did not include any past NFS records, and because all the data collection was done by the authors we consider these data and results highly accurate. In a combined data set for the ANF and DCNF for 1987 (n = 49) there was a highly significant inverse relationship between the number of woodpeckers per colony and the amount of mature forest removed. The number of woodpeckers per colony decreased as the amount of mature forest removal increased (Spear-man rank correlation, $r_s = -0.34$, $P = 0.007$). At 800 m (0.5 mi) this relationship was of borderline significance (Spearman rank correlation, n = 49, $r_s = -0.23$, $P = 0.054$). The number of woodpeckers per colony was not statistically correlated to the amount of hardwood midstory in colony sites ($r_s = -0.20$, $P = 0.082$) or colony isolation ($r_s = 0.12$, $P = 0.200$). Isolation, however, was significantly correlated to the amount of hardwood midstory in colony sites ($r_s = -0.38$, $P < 0.003$).

DISCUSSION

Declines and extirpations of red-cockaded woodpecker populations are occurring in other geographical areas of the bird's range (Baker 1982, 1983; Carter and others 1983; Jackson 1980; Thompson 1976). Walters and others (1988) observed a slight decline in the number of red-cockaded woodpecker groups in North Carolina. Typically, smaller populations are declining the most. Previous work on the ANF, DCNF, and SNF suggests that red-cockaded woodpecker populations were declining during the early 1970's (Jackson and others 1978). The lack of annual monitoring of most red-cockaded populations prevents accurate determination of population trends. No published data are available for large populations. Recent information indicates that there has been a lo-percent increase in the number of active colonies on the Francis Marion National Forest over the past 7 years (unpubl. data from the Francis Marion National Forest in South Carolina provided by Robert G. Hooper in 1988). The declines we have seen in small populations suggest an urgency to also monitor large populations to determine changes on population fringes and in areas where forest habitat is fragmented.

The factors contributing to the decline of the red-cockaded woodpecker on national forest lands in Texas are difficult to evaluate. Based on the extensive literature on the ecology of red-cockaded woodpeckers and observations concurrent with this survey, several contributing factors are suggested. Hardwood encroachment and a well-developed hardwood midstory have resulted in a vegetation structure that is not optimum for the species. Analyses of data from the ANF and DCNF indicate that there was a significantly greater abundance of hardwood midstory in colonies that have become inactive since 1983 and 1981, respectively, as compared to colonies that remained active in 1987. The need for frequent fire (Conner and Locke 1979, Jackson and others

1986, Stamps and others 1983), hardwood midstory control, and low basal areas (Hovis and Labisky 1985, Van Balen and Doerr 1978) in colony areas is well documented. The presence of hardwoods in and around red-cockaded woodpecker colony sites may increase competition for cavity trees with red-bellied woodpeckers *(Melanerpes carolinus)* and flying squirrels *(Glaucomys volans)* and increase the frequency with which pileated woodpeckers enlarge red-cockaded woodpecker cavities.

Our results also indicate that colony isolation has contributed to colonies becoming inactive and that the combination of clearcutting, SPB control cuts, and other nonforest land use was not statistically associated with colonies becoming inactive on the ANF and DCNF. Additional factors that need to be evaluated in relation to population declines are genetic complications resulting from small population sizes and possible lack of sufficient numbers of relict pines (>100 years old) for cavity trees. Population sizes of red-cockaded woodpeckers on the ANF, DCNF, and SNF are all well below the genetically based minimum viable population size (509 breeding pairs) determined by Reed and others (1988).

The relationships we detected between the number of woodpeckers per colony (clan or family group size) and habitat characteristics suggest that small woodpecker populations may be particularly sensitive to land use patterns within 400 m (0.25 mi) of colony sites. The amount of mature forest removal within 400 m (0.25 mi) of colony sites had a strong negative correlation with clan size. We realize that the presence of small woodpecker clans can indicate that new clans have recently formed, or in the case of single bird colonies, might be beginning to form. This would be true for increasing populations, and possibly true for stable ones. Our field observations, however, have indicated that many clans have decreased in size down to one woodpecker, and this solitary woodpecker, in most cases, has disappeared after 2 to 3 years, resulting in an inactive colony. We have concluded that our observations of small clan sizes in declining populations are the result of some type of negative effect. Walters and others (1988) have used clan size to evaluate red-cockaded woodpecker territory quality. Cutting or other nonforest land uses near woodpecker colony sites may affect red-cockaded woodpeckers in two ways. Cutting increases forest fragmentation and, in small populations where many colonies are isolated, may reduce the ability of dispersing woodpeckers to find neighboring colonies in need of replacement woodpeckers. Cutting may also increase travel distance and thus increase the energy demands of woodpeckers when foraging and trying to feed young woodpeckers in nest cavities. Clan size may therefore be affected either by reducing the number of young fledged or possibly by forcing nonbreeding adults to disperse from the parent colony because of insufficient foraging habitat. Of these two alternatives (fragmentation vs. foraging habitat sufficiency) we suggest that fragmentation has the greater influence on clan size. Depression of fledgling success through habitat insufficiency or forced early dispersal of nest helpers may also be reasons for smaller clan size and warrant future research and experimental analysis. However, regardless of the mechanism, increased mature forest removal within 400 m (0.25 mi) of woodpecker colonies was negatively associated with clan size in the small woodpecker populations we examined.

Much of the cutting within 400 m (0.25 mi) of woodpecker colonies has occurred in the past 5 years. Because red-cockaded woodpeckers live to be 5 to 8 years old, it is possible that sufficient time has passed for cutting to have affected woodpecker clan size but not loss or inactivation of colonies. Clans might dwindle in membership, but it might take as long as 10 years before cutting could have a detectable effect on colony inactivation. This line of reasoning agrees with our results; we detected no statistically significant effect of cutting on colony inactivation, but there was a highly significant relationship with clan size.

Any reduction in woodpecker clan size has a negative implication for the goal of increasing the number of active colonies in the future (recovery). We suggest that large clans are probably more likely to pioneer or bud (Hooper 1983) to form new colonies than small clans.

Recent studies (DeLotelle and others 1987, Porter and Labisky 1986) and the recovery plan (U.S. Fish and Wildlife Service 1985) suggest that populations in sparsely stocked forests may require more than 50 ha (125 acres) of foraging habitat. Sparse stocking of pine stems and stand age may not be the only factors that determine the quality of foraging habitat. Jackson and Jackson (1986) have suggested that the presence of extensive hardwood midstory in red-cockaded woodpecker foraging habitat may force female red-cockaded woodpeckers that normally forage more on lower regions of pines than males (Hooper and Lennartz 1981) to forage higher in pines, putting them in competition with the socially dominant male. If this is true, 50 ha (125 acres) of fully stocked mature pine forest with extensive hardwoods may not be sufficient foraging habitat. However, Hooper and Lennartz (1981) noted that male and female red-cockadeds commonly foraged close together on the trunk with no overt aggression or discernible interaction.

The presence of extensive hardwoods as observed in red-cockaded woodpecker foraging habitat may reduce the quality of the habitat by attracting pileated and red-bellied woodpeckers and increasing competition for food resources on pines. Also, if clearcuts on either Federal or private lands already exist around woodpecker colonies, further cutting in the area to control SPB or the loss of mature pine habitat as a result of pines being killed by SPB (Kulhavy and Conner 1986) might reduce available foraging habitat below what is optimum for clan maintenance or expansion. Modified shelter-wood cutting in the longleaf pine type is an alternative to clearcutting that would provide some additional foraging habitat within red-cockaded woodpecker home ranges and reduce the hazard of SPB attack to the stand while simultaneously creating potential nesting habitat (Conner and O'Halloran 1987). Recent data suggest that shelter-wood cuts can be of benefit to red-cockaded woodpeckers if the trees left standing are of sufficient age (80 to 120 years old) (R.N. Conner and A.E. Snow, unpubl. data).

It is often suggested that many undiscovered colonies exist on the national forests. We do not deny the possible existence of some undiscovered colonies and in fact hope that many more exist. However, the possible existence of significant numbers of such colonies should not be relied upon as a basis for management decisions.

The accuracy of our survey and the resulting population trend data obviously depend on the percentage of colonies actually present and whose locations are known as well as the accuracy of the original base data used for comparisons. Locations for a majority of the colonies have been known since the 1970's. As of 1988 fewer than 10 previously unknown active colonies have been located since 1983 on the 3 national forests. However, no intensive forest-wide inventory has been conducted during this period. Extensive searches on the ANF from 1983 to 1988 have revealed no additional active colonies in the vicinity of known colonies or elsewhere on the forest. It is also unlikely that additional colonies, when found, would be faring any differently than those currently known.

The apparent lack of establishment of new colonies is of major concern. Most known colonies show evidence of having been in existence for many years (abandoned cavity trees, old cavities with extensive plates). Evidence for the recent establishment of new colonies, as opposed to the discovery of long-existing colonies, is minimal throughout the South on public as well as private forest lands.

CONCLUSIONS AND SUGGESTIONS

Our results indicate that red-cockaded woodpecker populations on the ANF, DCNF, and SNF are in a severe decline and in danger of extirpation in the near future. We suggest that the following management activities be considered to stabilize red-cockaded woodpecker populations on the national forests and other Federal lands.

1. All initial red-cockaded management should be focused on active woodpecker colonies. Only *after* active colonies have received appropriate management should management be directed at inactive colonies (U.S. Fish and Wildlife Service 1985). However, it is still important to maintain inactive colonies, particularly those closest to active colonies (<5 km [<3 mi]), because they are the sites that have the highest probability for the formation of new woodpecker clans.
2. When thinning cuts are made within colony buffer areas, we recommend that the entire colony be put under one buffer; that basal area be reduced to 14 m^2/ha (60 ft^2/acre) in the entire colony area; and that relict pines (>100 years old), other mature pines, and some younger pines be left standing. Thought needs to be given as to how the "forest area" within the colony zone will be perpetuated. Pine reproduction needs to be protected in older colony areas where stand deterioration is occurring and sufficiently sized gaps in the canopy appear. If midstory pines exist in colony areas, some should be protected to provide possible replacement trees when gaps in the canopy occur. In the long-term, we suggest that colony areas be managed as multiaged pine stands composed of small differently aged patches where possible.
3. Our data and research throughout the South indicate that understory and midstory hardwoods are detrimental to both the survival and population recovery of the red-cockaded woodpecker (U.S. Fish and Wildlife Service 1985). To ensure maximum opportunity for population increases, understory and midstory hardwood vegetation control in woodpecker colony areas is vital.
4. A more aggressive prescribed burning program within woodpecker colonies and within each colony home range is needed. Fire at least every 2 years on longleaf sites and every 3 to 4 years on loblolly sites (or as soon as the site will carry a fire again) is needed. After extreme hazard has been reduced by winter and spring fires, we suggest that late summer (August and September) fires be used as a more effective means to control hardwoods and thin young pines (Jackson and others 1986).
5. We recommend that mature stands within 1,200 m (0.75 mi) of active woodpecker colonies be thinned to a basal area of 16 m^2/ha (70 ft^2/acre) but that all relict pines and some of the

other mature pines in thinned stands not be cut. Such thinning would reduce the hazard of SPB infestations near woodpecker colonies (Jackson and others 1986, U.S. Fish and Wildlife Service 1985). Pines left during thinning operations within and outside of colony areas should be similar to pines selected by red-cockaded woodpeckers for cavity trees as described by Conner and O'Halloran (1987).

We suggest that the following management recommendations be considered for use on national forest lands in an effort to create higher quality habitat for red-cockaded woodpeckers in order to stabilize and hopefully increase the sizes of small populations (<50 active colonies).

1. We recommend that, where silviculturally feasible, irregular shelterwood cutting (Smith 1986) in a longleaf pine forest type to a basal area of 9 m^2/ha (40 ft^2/acre) and irregular shelterwood cutting in loblolly and shortleaf pine types to a basal area of 7 m^2/ha (30 ft^2/acre) within 1,200 m (0.75 mi) of active colonies be selected as the regeneration method if regeneration cuts are planned. However, 7 m^2/ha (30 ft^2/acre) is below the optimum basal area for colony areas and is recommended for silvicultural reasons. These alternative methods would provide an immediate supply of potential nesting habitat if residual trees are of sufficient age (80-120 years old) (Conner 1979, Conner and Locke 1982, Conner and O'Halloran 1987) and would not totally remove any of the colony's home range from foraging habitat. We recommend that the residual trees be left standing in perpetuity for the maximum possible recruitment of new red-cockaded woodpecker colonies and to reduce habitat fragmentation. We also suggest that these natural regeneration methods be considered for use around inactive colonies that are within 5 km (3 mi) of active colonies.
2. In order to minimize fragmentation and approximate the mosaic of small, even-aged stands or patches of the original longleaf pine forests as described by Chapman (1909), we suggest that regeneration cut size during shelterwood cutting range from 2 to 6 ha (5-15 acres) in size and average about 4 ha (10 acres) at the maximum. Obviously, smaller cut sizes would reduce fragmentation problems even further. Small cut sizes would create patches that approximate the sizes of many existing woodpecker colonies and provide a range of all age classes within an area roughly equivalent to the red-cockaded woodpecker's home range if rotation age is set at 120 years. A rotation age of 120 years would greatly benefit small red-cockaded woodpecker populations. Hardwood midstory vegetation in patches of this size could still be controlled easily with prescribed fire.
3. In view of the relationship between the number of red-cockaded woodpeckers per colony and the amount of cutting within 400 m (0.25 mi) of active colony sites we suggest that forest managers consider thinning stands that are within 400 m (0.25 mi) of active colonies to a basal area of 16 m^2/ha (70 ft^2/acres) rather than making regeneration cuts where the populations consist of fewer than 50 active colonies. This suggestion may be particularly important for the stabilization of populations consisting of <50 active colonies such as those on the ANF, DCNF, and SNF. Implementation of this suggestion would reduce habitat fragmentation around active colonies and minimize fragmentation and loss of foraging habitat if direct control (cut-and-leave or cut-and-remove) is necessary to control SPB infestations.
4. We suggest that the provision and maintenance of relatively direct forest corridors between active colonies be included during timber sale and forest compartment prescription planning to help reduce colony isolation and habitat fragmentation (Jackson 1976, Ligon and others 1986). Corridors should be at least 400 m (0.25 mi) wide and consist of trees at least 30 years old. These corridors should also be maintained between active and inactive colonies that are within 5 km (3 mi) of active colonies. On forests where several population clusters (aggregations of active colonies) exist, population clusters should be connected by corridors. Corridors of this width could potentially provide future habitat for population expansion to meet long-term recovery goals.

FOREST AREA AFFECTED BY RECOMMENDATIONS

If followed, the recommendations and suggestions made in this paper will obviously have an impact on timber production. An evaluation of the land area within a 1,200-m (0.75-mi) radius of active red-cockaded woodpecker colonies and inactive colonies within 5 km (3 mi) of active colonies indicates that 30,109 ha (74,153 acres) would be affected by the recommendations. This area represents 12.2 percent of the total national forest land in eastern Texas (McWilliams and Lord 1988). The affected areas for the Angelina (9,345 ha 123,090 acres]), Davy Crockett (14, 663 ha [36, 231 acres]), and Sabine (6,002 ha [14, 832 acres]) National Forests represent 15.0 percent, 22.4 percent, and 9.4 percent respectively of the area of each forest. The values presented actually overestimate the land area affected because some of the forest within 1,200 m (0.75 mi) of colonies is not in pine timber types and thus would not be affected by the recommendations. National forest land on the Sam Houston National Forest is not affected by our recommendations because the number of active colonies on that forest exceeds 50. Our recommendations would not have an impact on private or industrial forest lands.

McWilliams and Lord (1988) report the area of timberland in eastern Texas by ownership and forest type. Using their data, the area affected by our recommendations constitutes 0.64 percent of the total timberland of eastern Texas. If only pine timber types are considered, and it is assumed all habitat within 1,200 m (0.75 mi) of colonies is pine type, 16.7 percent of national forest land or 1.76 percent of all eastern Texas pine timberlands would be affected.

Of the affected national forest pine timberland mentioned above, even-aged timber management and harvesting would still occur on approximately 90 percent of the total. Shelterwood harvesting would be used instead of clearcutting on 27,198 ha (67,206 acres) of the 30,109 ha (73,153 acres) of pine forest lands affected by our recommendations. The remaining 2,911 ha (7,193 acres) would produce timber at a reduced level by thinning (assuming there were 58 active colonies in 1988). The 2,911 ha (7,193 acres) of pine timberlands would be the only land area severely impacted for timber production by our recommendations. This 2,911 ha (7,193 acres) represents 1.66 percent of all national forest pine timberlands in eastern Texas, 0.18 percent of all pine type timberlands in eastern Texas, and 0.06 percent of all timberlands in eastern Texas. This value for the pine forest area that is severely affected by our recommendations is still an overestimation, The actual area impacted would be somewhat less because our recommendation only affects national forest lands within 400 m (0.25 mi) of the 58 active colonies and not private lands that fall within this radius.

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Abundant hardwood midstory, colony isolation, and habitat fragmentation are believed to be the causes for severe population declines of red-cockaded woodpeckers on three national forests in eastern Texas.

Keywords: colony isolation, habitat fragmentation, hardwood midstory, population decline, shelterwood cutting.